International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review of Asphalt Pavement and its Mixtures

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ABSTRACT

Asphalt, also known as bitumen, is derived mostly from petroleum and is a viscous material that is thick, sticky, black, and has a high viscosity. Pitch is a mineral that can be found in both natural deposits and cleaned-up products. Asphalt was known as asphaltum before the turn of the twentieth century. The world's largest natural asphalt deposits are discovered in Pitch Lake, which is located in La Brea, southwest Trinidad, an Antilles island off the northeastern coast of Venezuela. The main thing that asphalt is used for is building roads, which takes up 70% of the asphalt that is mined. In this case, the asphalt is used as glue, and the binder is mixed with the building materials to make asphalt concrete. Other than concrete, the main things that can be made from asphalt are sealants for flat roofs, roofing felts, and bituminous waterproofing products. "Crude bitumen" is the name for asphalt that comes from the ground and has a consistency similar to that of cold molasses. But when the crude oil goes through fractional distillation, in which it is heated to 525 °C (977 °F), the asphalt that is made is called "refined bitumen." The largest natural reserve of asphalt is in the Canadian province of Alberta.

INTRODUCTION

Pavement condition is a critical aspect for the development of countries. According to the World Bank, the density of paved roads in good condition varies from 40 km/million inhabitants in low-income economies to 470 middle-income and 8,550 in high-income economies. Arguably, the knowledge of pavement condition is fundamental to provide safety, comfort, and environmental quality for road users. The service life of most of the major roads in the US is between 5 to 7 years, prior to the first maintenance operation. Normally, roads require major rehabilitation after 20 years of service life. This is mainly due to the harsh environmental conditions and/or heavy traffic loading, which might be exacerbated by poor construction techniques. The pavement service life can be extended through applying timely and appropriate rehabilitation and maintenance measures. An appropriate pavement management system results in a drastic decrease in repair and reconstruction costs.

Smart pavement monitoring methods have been growing rapidly as a result of the advanced sensing, computing and communications technologies. Pavement distresses such as rutting and cracking are among the most detrimental damage forms. A robust pavement performance monitoring system should be able to identify the type, extent, and severity of failures in order to diagnose the problem and prescribe the most effective repair strategy. Visual inspection by well-trained pavement experts is the simplest pavement distress monitoring method. Despite the simplicity of this method, it might result in bias and unreliable data collection and can impose extra cost and time on the project. In addition, this method may involve lane closures and safety hazards for both the traveling vehicles and the pavement inspector. To overcome the downsides of visual inspection, a number of automated pavement condition assessment methods have been proposed.

TYPES OF ASPHALT CONCRETE OR (BITUMINIOUS MIXTURE)

Asphalt concrete utilised in the construction of road surfaces, airports and parking lots, among other places. When it's placed down and compacted in layers, it's made up of asphalt and mineral aggregate. Asphalt and aggregate can be mixed together in a variety of ways.

HOT MIX ASPHALT

Asphalt pavement refers to any paved road surfaced with asphalt. Hot Mix Asphalt (HMA) is a combination of approximately 95% stone, sand, or gravel bound together by asphalt cement, a product of crude oil. Asphalt cement is heated aggregate, combined, and mixed with the aggregate at an HMA facility. The resulting Hot Mix Asphalt is loaded into trucks for transport to the paving site. The trucks dump the Hot Mix Asphalt into hoppers located at the front of paving machines. The asphalt is placed, and then compacted using a heavy roller, which is driven over the asphalt. Traffic is generally permitted on the pavement as soon as the pavement has cooled. Hot Mix Asphalt (HMA) is a hot mixture which involved heating, mixing and coating of aggregates and bitumen at the desired mixing temperature. It is stated in the Malaysian Public Works Department specification (PWD) that the mixing temperature to produce HMA is between 150 to 190°C, depending on the binder type. By applying targeted mixing temperature in HMA production, the quality of pavement can be enhanced with good resistance against deformation and longer service life. Other than mixing temperature, compaction temperature also influences the quality of HMA. The temperature of HMA during on-site construction for paving is generally around 150°C in order to ensure the applicability of bitumen in coating the aggregate particles by thin film. This is because as the compaction temperature decreases, the bitumen becomes more viscous and resists compaction, which results in less air voids reduction. It should be noted that the HMA must be compacted to achieve the desired level of density or air voids content as the density controls its durability

DENSE-GRADED MIXES

Dense bituminous macadam is another name for this form of bituminous concrete, which is a well-graded HMA with a good proportion of all elements. A deep graded mix is virtually impenetrable if it is made and planned correctly. Nominal maximum aggregate size is used to describe dense-graded mixtures, which in turn can be further broken down into fine-graded or coarse-graded varieties. There are more sand- and fine-sized particles in fine-graded mixes than in coarse-graded mixtures. It may be used on any type of surface and in any type of traffic. It has a high degree of tensile strength. Asphalt binder and well-graded aggregate are employed in the construction (with or without modifiers).

STONE MATRIX ASPHALT (SMA)

Stone matrix asphalt (SMA), Some people are referring to it as stone mastic asphalt, which is an HMA that is gap-graded and optimized for heavy highways. Stone skeletons made with SMA's high-coarse aggregate composition resist irreversible deformation. To keep the bitumen in place, fibres are added to a mastic of bitumen and filler, which will then be poured into the stone skeleton to keep it stable throughout transport and placement. 70% to 80% coarse aggregate, 8% to 13% filler, 6.0–7.0% binder, and 0.3 percent fibre make up the typical SMA makeup. Stone-on-stone contact in SMA mixes is greater than in traditional dense graded asphalt (DGA) mixes, which helps explain its deformation resistance. Higher bitumen content, a thicker bitumen coating, and lower air gaps contribute to improved binder durability. Flexibility is further enhanced by the high bitumen concentration. In order to keep bitumen from evaporating during shipment and installation, a tiny amount of cellulose or mineral fibre might be added. SMA mixes don't have a set of design rules. Coarse aggregate structure and mastic composition, together with the resulting surface texture and stability, are primarily governed by the aggregate grading and the kind and percentage of filler and binder. Rut resistance as durability were enhanced because to SMA. Fatigue and tensile strength are both high on this material's strength spectrum. For the most part, SMA is utilised for surface courses on high-volume roadways. Gap graded aggregate, modified asphalt binder, and fibre filler are utilised in SMA. Other advantages of SMA include decreased wet weather friction, lower tyre noise, and less severe reflective cracking (all owing to the finer surface texture). Asphalt binder drain-down during construction is minimised, the amount of asphalt binder with in mix is increased, and the mix durability is improved by using mineral fillers and additions.

OPEN-GRADED MIXES

Unlike dense-graded mixes and SMA, A water-permeable open-graded HMA mixture is devised. Crushed stone (or gravel) and a small percentage of artificial sands are the sole materials used in open-graded mixtures. The following are two examples of open-graded mixes:

Friction surface with an open gradation (OGFC). Typically 15% air spaces, and no maximum air voids are stated.

Permeable bases with asphalt treatment (ATPB). Due to its application beneath dense-graded HMA, SMA or Portland cement concrete, OGFC has less severe criteria.

OGFC - Only used on the surface. In rainy conditions, they decrease tyre splash/spray and often produce smoother surfaces than dense-graded HMA. Tire-road noise can be reduced with up to 50% thanks to their large air spaces.

ATPB – Drainage layer beneath dense-graded HMA, SMA, or PCC.

Asphalt binder, crushed stone or gravel, & synthetic sand are among the often-utilised building materials (with modifiers). While the cost per tonne of OGFC was higher than dense-graded HMA, the unit weight of the mix when in-place is lower, which partially compensates the higher per tonne price. Pores in the mix is created by the open gradation and are critical to its optimal operation. Low-speed traffic, excessive dirt on the road, and other factors that block these pores will have a negative impact on performance.

LITERATURE REVIEW

Nobakht, M., Zhang, D et al,(2020) Moisture damage has a major impact on the durability of asphalt concrete, leading to premature degradation of asphalt pavements. To determine how vulnerable asphalt mixes are to moisture degradation, agencies and researchers have used a variety of tests and conditioning procedures. Predictive models that take into consideration the effects of moisture on the basic mechanistic features of asphalt concrete are, however, still needed. The purpose of this study is to create a cohesive moisture damage model and an adhesive moisture damage model to anticipate the amount of damage that will be caused by the diffusion of moisture in asphalt concrete. Intermolecular binding energy/force and the processes of cohesive and adhesive failures are used to inform the development of these models. They think that asphalt pavements primarily use water vapor diffusion to move moisture around. Dynamic modulus testing of Fine Asphalt Matrix mixes and Bitumen Bond Strength testing of the adhesive bond between the aggregate and asphalt binder are used to calibrate and validate the models, respectively. Validation results demonstrate the accuracy of the proposed models in estimating asphalt mixes' susceptibility to adhesive and cohesive moisture degradation.

Barri, K., Jahangiri, B. et al,(2020) Over time, pavement systems deteriorate owing to a variety of factors, including the natural deterioration of materials, wear and tear, overloading, weather, lack of preventative maintenance, and poor quality control measures. Evaluation of the pavement's state is crucial for making decisions about preventative maintenance and restoration. This research introduces a novel approach to the comprehensive characterisation of asphalt concrete. Mobile phones and a pocketable, all-in-one near-infrared (NIR) molecular sensor are at the heart of the suggested approach. The NIR spectrometer illuminates a sample with a broad spectrum of near-infrared light, which is subsequently absorbed, transmitted, reflected, or scattered by the sample's surface in one of several ways. To do this, we measure the light's intensity as a function of wavelength before and after it strikes the sample. Next, we account for absorbance and scattering to get the sample's diffuse reflectance. Asphalt binders of varying grades, ages, and rubber components are characterized using the suggested mobile smartphone-based NIR technique. As such, several examples of the binder are examined in the 740-1040 nm spectrum. The findings show that the spectra produced by asphalt binders of varying grades and ages are highly variable.

Pan, P., Wu, S. et al,(2017) Solar energy collecting and snow melting efficiency of asphalt solar collectors have been proposed to be enhanced by using conductive asphalt concrete with high thermal conductivity (ASC). This paper's goals are to (1) shed light on the selection of raw materials for making conductive asphalt concrete and (2) identify how the development of the material's thermal properties is influenced by environmental conditions. The Thermal Constant Analyzer was used to investigate the asphalt concrete's thermal conductivity. The experimental results demonstrated that the asphalt binder's low proportion masks its effect on the thermal characteristics of asphalt concrete, while the aggregate and conductive filler have a far larger impact. When making conductive asphalt concrete, it's best to use a filler that has a higher thermal conductivity and mineral aggregate to increase the concrete's overall conductivity. The real thermal properties of asphalt concrete should be determined by considering the variation in these values across a range of temperature and moisture conditions. Asphalt concrete's thermal characteristics were not noticeably different before and after aging. As a result of volume expansion and bond degradation, freezing and thawing cycles can have a significant impact on the thermal properties of conductive asphalt concrete.

Underwood, B. S. (2016) Building and characterizing a mechanistic model to explain the asphalt cement and asphalt mastic fatigue process is the primary goal of the study reported in this paper. Asphalt cement is an intricate blend of hydrocarbons with a wide range of molecular weights, polarities, and aromatic structures. When this cement is mixed with mineral particles smaller than 75 mm, the result is asphalt mastic. Most paved roads in the world are constructed using asphalt concrete, which is made by combining these components with fine and coarse aggregate particles. Fatigue cracking is a common failure mode for these pavements since they experience millions of load applications over their service life. Therefore, there is significant interest in creating methods to foretell the likelihood of cracking, aid in the design of materials that are more resistant to cracking, and shed light on the mechanisms driving the suffering.

Hou, X., Xiao, F. et al,(2018) During both its construction and service life, asphalt pavement is subjected to the sun, oxygen, water, ambient temperature, and other climate elements, which age or oxidize the asphalt binder and hasten the pavement's deterioration. The effects of time on asphalt materials have been studied using a variety of standard methods, including rheological testing, Fourier transform infrared spectroscopy (FTIR), Gel Permeation Chromatography (GPC), etc. Their practical implementation was hindered by issues like the difficulty of the testing procedures and the high cost of the necessary testing equipment. In this research, spectrophotometry was used for the first time to investigate how asphalt binders change over time. Through the use of correlation analysis, we created a system for preparing and testing samples and then determined whether or not the system was practical. Experiments showed that asphalt aging may be characterized using a 2 g/L "toluene-heptane" emulsion (0.2 g/mL in toluene, 2 g/L in heptane) and an absorbance area test from 700 nm to 900 nm. The absorbance change of asphalt during the aging method was also shown to be due to the increasing asphaltene by the test and statistical data. In addition, the FTIR analysis validated the viability of spectrophotometry for describing asphalt's deterioration over time.

Zhu, J., Ma, T. et al,(2020) Considering the great disparity in particle structure and composition of RAP materials, their performance is very variable and erratic. Fine and coarse aggregates bound together by asphalt binder make up certain RAP particles, whereas fine aggregates hold together others. Furthermore, shards of asphalt have accumulated atop lone pieces of gravel. The structural nature of RAP material makes it susceptible to degradation during the cold recycling process, which in turn has a significant impact on the performance of the regenerated asphalt mixture. Initial results from an examination into the agglomeration of three different RAP materials using asphalt extraction, modified LA abrasion, and a mixer are presented in this article. This research contributes to the standardization of RAP in mix design and cold recycling procedures. Further research into the effect of agglomeration degree on mix design and cold mixture performance is also recommended.

Li, R., Xiao, F. et al,(2017) Nano-material, by virtue of its high surface area and small size, exhibits distinct characteristics in comparison to the ordinary material and demonstrates certain innovative qualities and remarkable features that make it viable to apply in the field of asphalt pavement as an additive. This article provides an overview of the primary nanomaterials and associated methods utilized for nano-modified asphalts, along with a discussion of their primary performance features at different stages of development. Conventional test results, such as viscosity, dynamic modulus, stiffness, rut depth, indirect tensile strength, and so on, were used to characterize nano-modified asphalts, and cutting-edge technologies, such as atomic force microscopy, scanning electron microscopy, X-ray diffraction, and Fourier transform infrared spectroscopy, were employed to efficiently explore their micro structures and molecular components.

Zhang, Z., & Oeser, M. (2020) Fatigue loading degrades the residual strength of the asphalt mixture, which leads to fatigue failure. Damage accumulation in asphalt mixture under fatigue loading can be better understood with a description of the strength degradation that occurs. The purpose of this research is to create a model of asphalt mixture's residual strength after it has been subjected to repeated loading, and to characterize the cumulative damage that has occurred. The first step was to develop a damage evolution model using the theory of continuum damage mechanics (CDM).

Xu, S., Liu, X. et al,(2021) Healing of extrinsic asphalt pavement deterioration using the rejuvenator encapsulation approach demonstrated promising results. A microcrack in the asphalt triggers the capsules to begin mending on demand. The rejuvenator is released from the capsule when the microcrack comes into contact with it, thanks to the fracture energy at the tip of the crack. In order to stop the further deterioration of the asphalt pavement, the released rejuvenator wets the crack surfaces, diffuses through and softens the old bitumen, and then brings the two fractured edges into contact. The effectiveness and speed with which damage is repaired are both affected by the rejuvenator used, therefore it's crucial to select a rejuvenator that can effectively restore the qualities of bitumen that have degraded with age and demonstrate sustained performance once the damage has been repaired. In order to accomplish this goal, the physical qualities, rheological properties, chemical properties, and performance after re-aging of rejuvenated bitumen from three distinct rejuvenators were evaluated and ranked.

Rodríguez-Fernández, I., Baheri, F. T et al,(2020) Most used tires end up in landfills around the world, which has disastrous effects on the environment and poses special dangers to people's health (e.g. fire, pests and soil contamination). The growing concern for the environment has led to the widespread adoption of crumb rubber modified asphalt as a means of reusing old tires. Crumb rubber (CR), often known as recycled tire rubber, is a popular ingredient in hot mix asphalt mixtures because of the mechanical performance benefits it provides. By correlating mechanical performances with microstructural characterizations, this study aims to examine the impact of adding crumb rubber to asphalt mixtures through the dry process.

Yao, Z., Zhu, H. et al,(2017) Moisture damage is one of the biggest problems with asphalt pavements because it makes the pavement work less well and last much less long. At the moment, most of the attention is on studying how water affects asphalt on a large scale. At the micro level, however, the complex interactions between water, asphalt, and aggregates make it hard for macro testing to give a clear picture of how this process works. In this study, two promising micromechanical tests, atomic force microscopy (AFM) and nanoindentation, were used to measure the micromechanical properties of asphalt binder and mixture samples before and after they were damaged by water. To compare data, the freeze-thaw splitting test and the surface energy method were also used.

Sudarsanan, N., Karpurapu, R. et al,(2019) Inadequate maintenance of asphalt roads leads to early failure due to reflective cracking. Different geosynthetics are utilized at the interfaces of surface layers to manage the reflecting fractures. Flexural strength and interfacial bonding are crucial aspects that determine their effectiveness. Single-edge notched beam (SENB) tests can reliably examine the fracture energy that initiates crack formation and growth. In order to conduct quasi-static SENB tests, samples of asphalt with two layers were taken from newly constructed pavement sections. Geosynthetic reinforcement did not significantly enhance AC prior to cracking, although it did reduce crack growth rate. There has been a transition from a quasi-brittle to a ductile failure mode in reinforced specimens. With knowledge of the bond strength of the reinforced AC layers and their temperatures, an equation is proposed to predict the fracture initiation force of a SENB sample.

Pan, P., Wu, S. et al,(2015) Pavement snow melting/deicing by an asphalt pavement electrical heater is aided by conductive asphalt concrete. It's cutting-edge tech that will make winter driving safer in the near future. Using the Joule heating equation, an electric current might melt snow and ice from an asphalt pavement by traveling through conductive asphalt concrete (a conductor). An overview of conductive asphalt concrete's development, construction methods, performance evaluation, and engineering uses is presented here. In the meantime, the qualities of conductive additives are used to determine the mechanism of conductivity improvement. The influence of service circumstances on resistivity is also assessed. Despite its limited use in the transportation sector, the environmental and safety benefits of the electrical heater technology for asphalt pavement are clear.

Mohajerani, A., Bakaric, J. et al ,(2017) Ultimately, the UHI effect in metropolitan settings is shown to be significantly influenced by the thermal properties of asphalt concrete. There is an ongoing need to lessen the detrimental effects of the UHI on urban health, well-being, and quality of life. The extensive use of buildings and other heat-insulating materials renders a 536 A. obsolete. Several methods have been proposed in the literature for mitigating the consequences of climate change, including the use of reflective and evaporative pavements, environmental greening, and the harnessing of wind and water as cooling agents. It has been discovered that a mix of approaches is the most efficient way to lessen the impact of UHI. To find the most effective strategy for reducing UHI, researchers are exploring a wide variety of approaches and will need to examine their effectiveness across the year.

Rahman, M. T., Mohajerani, A.,et al,(2020) The problem of managing garbage has recently gained international attention. Waste from these goods is choking landfills and cutting into usable land. Polluting leachate seeps out of landfills and into the surrounding area. Toxic airborne pollutants are released into the atmosphere during the traditional cremation procedure. Sustainable waste management and recycling strategies are the focus of persistent investigation by scientists. If you want to get rid of trash quickly and effectively, recycling and reusing are your best bets. Since various types of trash may be converted into asphalt concrete and bitumen, the paving business is one of the more promising industries today. In this study, we examine the potential for more research after analyzing the outcomes of certain substantial studies.

PAVEMENT DETERIORATION AND ITS TYPES

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions.

1. Fatigue cracking (Alligator cracking):

People frequently refer to fatigue cracking as "alligator cracking." This is a collection of fractures that unite to form small, irregularly shaped pieces of pavement. It occurs when the surface layer or base fails as a result of frequent traffic loads (fatigue). The end effect is potholes. Alligator cracking is typically caused by base or drainage issues. Small holes or tears can be repaired using a patch or area repair. Greater regions must be reclaimed or restored. Drainage must be carefully monitored at all times.

1. Longitudinal cracking:

Longitudinal cracks are long cracks that run parallel to the road's centre line. These can be caused by frost heaving or joint failures, or they might be caused by the structure's weight. To choose the best remedy, you must first determine what caused the problem. More parallel cracks may emerge in the future from the first crack. This is known as "deterioration," and it is usually an indication that crack fixes are not the best answer.

Transverse cracking :

Transverse cracks form practically perpendicular to the centerline of the road. They have the same causes as longitudinal cracks and are equally spaced. Transverse cracks will first be spaced widely apart (over 20 feet apart). Most of the time, they begin as hairline or very narrow cracks that get wider over time. If the first crack is not properly sealed and addressed, new cracks or several cracks will form adjacent to it. The reasons for and methods for repairing transverse cracks are the same as those for longitudinal cracks. Temperature issues can also cause cracking at low temperatures if the asphalt cement is excessively firm.

Block cracking:

The term "block cracking" refers to a sequence of cracks that connect and split up the pavement into odd-shaped pieces. This can occur when transverse and longitudinal cracks collide. They can also occur as a result of inadequate ground preparation when the structure was erected. A thin wearing course can be used to repair minor block cracking. Overlays and recycling may be required as the cracking worsens. If faults with the foundation are discovered, it may be essential to repair or rebuild it. The image depicts medium to severe block cracking.

CONCLUSION

Bituminous roads are ones that are constructed with bitumen as the glue. It is composed of a close mixture of rocks, mineral filler, and bitumen. The type and quantity of filler material used has an impact on how well and how long a bituminous road will survive. As the filler is mixed into the asphaltic cement, it stiffens it. Bituminous mixes frequently use cement, lime, granite powder, stone dust, and fine sand as filler. Cement, lime, and granite powder are expensive and should be utilised for anything else. Fine sand, ash, waste concrete dust, and brick dust that passes through a 0.075 mm sieve appear to function well as filler materials. A great mixture of research has been done in recent years on how to use waste powder as a filler in asphalt mixtures. Jordanian oil shale fly ash, bag house fines, recycled waste lime, ash from burning municipal solid waste, and waste ceramic materials have all been used as fillers for phosphate waste. It was demonstrated that these sorts of recycled filler could be utilised in asphalt mixtures and that the asphalt's performance would improve.

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